On possible realizations of backward-wave regime and negative refraction in chiral composites

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It is well known that negative refraction happens at an interface between a usual isotropic medium (vacuum, for example) and a material with negative parameters (called Veselago medium, double-negative material, or backward-wave medium). However, recent studies have shown that backward waves can propagate in materials with positive parameters provided one of the materials is *chiral* (S. Tretyakov, I. Nefedov, A. Sihvola, S. Maslovski, C.Simovski, Waves and energy in chiral nihility, *J. Electromagn. Waves Applic.,* vol. 17, no. 5, pp. 695-706, 2003; J. Pendry, A Chiral route to negative refraction, *Science,* vol. 306, pp. 1353-1955, 2004; H. Dakhcha, O. Ouchetto, S. Zouhdi, Chirality effects on metamaterial slabs, Proc. of *Bianisotropics'2004 - 10th Conference on Complex Media and Metamaterials,* pp. 132-135, Ghent, Belgium, September 22-24, 2004).

The physics of the effect is very simple: The propagation constants of two eigenwaves in isotropic chiral media equal $\beta = (n \pm \kappa)k_0$, where $n = \sqrt{\varepsilon\mu}$ is the usual refractive index, κ is the chirality parameter, and k_0 is the free-space wavenumber. Near a resonance of the inclusions forming the material the real part of the refractive index *n* can become smaller than the real part of the chirality parameter κ. It means that one of the two eigenwaves is a backward wave, because its phase velocity is negative but the energy transport velocity is positive. At an interface between a usual isotropic material and such medium negative refraction takes place for this polarization (waves of the other polarization refract positively). This is a very exciting new opportunity to realize negative refraction and related effects in the optical region in effectively uniform media (the characteristic dimensions in the material can be much smaller than the wavelength).

To realize the effect, Pendry (*Science*, 2004) proposed to use a double-phase composite, embedding resonant dielectric phase in a chiral background. Tretyakov et al. *(JEWA*, 2003) proposed to utilize the resonant regime of a single-phase chiral material, for instance, made of helical-shaped inclusions. In this presentation, we will give an overview of backward-wave regime in chiral media and discuss how such regimes can be practically realized using both proposed scenarios. Numerical estimations for the frequency dependence of material parameters near the appropriate resonances will be shown. We will demonstrate that resonant behaviour of background permittivity (as in the design of Pendry) very strongly influences the effective chirality parameter, which can make it very difficult to achieve the desired effect.